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Impacts of global climate change on the Mediterranean Region: Adana as a case study

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Abstract

The effects of climate change on Mediterranean region are known to include increases in temperature, decreases in precipitation and water exiguity. The original Mediterranean climate prevails along the southern coast of Turkey causes alterations in both climate parameters and perceived temperature by changes in the temperature, precipitation, and humidity values. In this study Adana which is located in the eastern part of the Mediterranean region, was chosen because of being the best indicator of changes in and the effects on the Mediterranean climate. As for the method, the Mann-Kendall rank correlation test (M-K) was applied to temperature, precipitation and humidity variables in Adana and then with the help of the Humidex index, perceived temperature values of the area were calculated in order to apply trend analysis. Especially in terms of average and minimum temperature values, strong positive trends were observed in temperature variables, while both strong positive and strong negative trends were observed in humidity variables. During the summer season strong increases were observed in perceived temperature at all weather stations except for Karataş and Tufanbeyli. Insignificant decreases in winter precipitation, and increases were observed during the dry period. These results were interpreted as increasing number and severity of heat waves due to climate changes.

Keywords: Climate change; Mediterranean climate; perceived temperature; trend analysis; climate of Adana.

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1. Introduction

Throughout history, the climate of the world has altered many times. This process occurred slowly in the past. However, with the industrialization which started in the 19th century, people started to affect the natural climate. The world's energy balance is based on the overuse of fossil-fuels. This degradation has started to affect climates by global warming which has been especially observed from the second half of the 20th century. In other words, long-term climate change is being experienced within the short time period of human influence. Climate changes that occurred in the short period have very important negative effects (Türkeş et al., 2000).

The warming trend observed in average global temperature is not distributed evenly on a worldwide scale. Long-term warming trends occur much more at 40°-70° North latitudes than in the rest of world. Indeed, the biggest effects of climate changes are observed in countries located at middle and high latitudes. In the list of countries, Turkey and especially the Mediterranean region would be the most affected side because of its geographical location (Cosun and Karabulut, 2009).

In this study, alterations were observed in the parameters of temperature, humidity and precipitation in Adana which is located on the Mediterranean coast of Turkey. Adana was chosen because of the fact that its climate features represent both its own climate and Mediterranean climate.

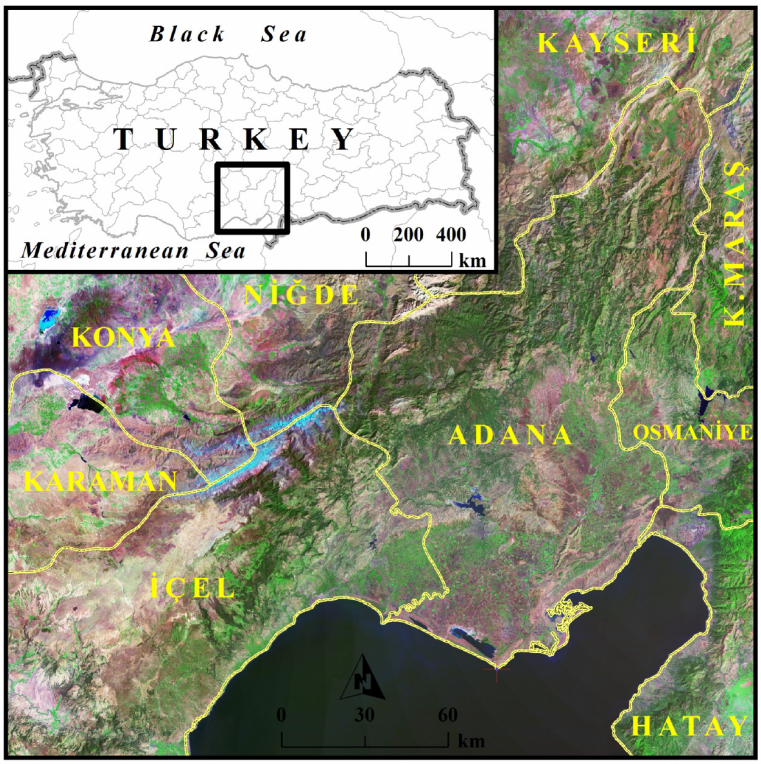

Fig. 1. Location of Study Area.

2. Description of the Study Area

Adana is located on the south coast of Turkey, in the eastern part of the East Mediterranean basin, and also in the Taurus orogenic system, between the Ecemiş and Yumurtalık faults. It is bordered by Kahramanmaraş and Osmaniye to the east, Hatay to the southwest, Mersin and Niğde to the west, Kayseri to the north and the Mediterranean to the south (Fig. 1).

The study area can be divided into hilly and lowland areas. The south of the area is characterized by lower lands which are parts of the Çukurova Delta and northern parts include in the Taurus orogenic system. There are also high plateaus in the hilly areas (Fig. 2).

The elevation difference between the south and north parts reflect the climate characteristics which lead to different climatic conditions in the interior and coastal regions.

In this study the monthly average maximum, minimum and average temperatures and total precipitation and relative humidity of the Central Adana, Karataş, Yumurtalık, Ceyhan and Kozan and Tufanbeyli meteorological stations were used. Tufanbeyli station represents a continental climate and the rest represent the Mediterranean climate (Table 1). The data range was formed by climate RASAT as 32 years (1980-2011) for Tufanbeyli and 37 years (1975-2011) for the other stations.

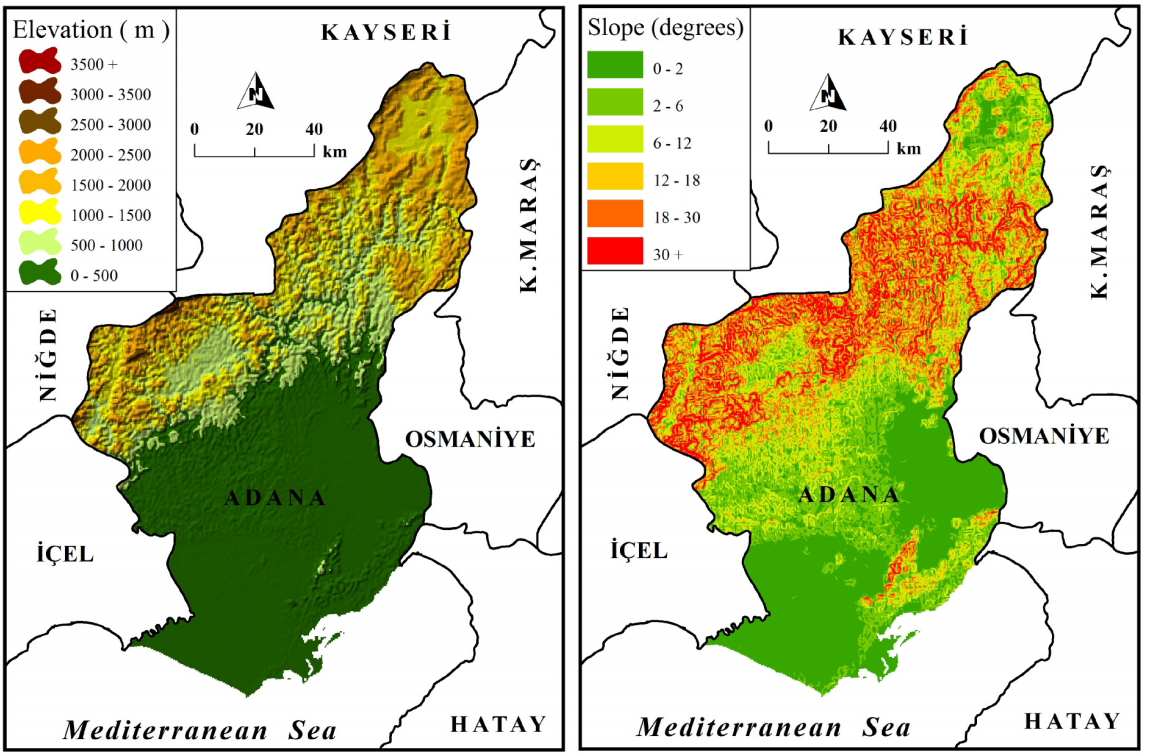

Fig. 2. Digital Elevation Model (DEM) and Slope Map of Study Area.

The Mann-Kendall Rank Correlation Test (M-K) method was applied to the temperature values, while humidity and precipitation values were provided by the Turkish Meteorological Service.

Afterwards, the perceived temperatures relative to the temperature and humidity values were evaluated using the "Humidity Index'' (Masterton and Richardson, 1979). Then these evaluations were applied to the M-K trend test. Only summer season data were evaluated in this particular index.

According to the Conrad Formula (Conrad and Pollak,1950), Adana (75%), Yumurtalık and Karataş (85%), Kozan (55%), Ceyhan (78%) and Tufanbeyli (22%) have maritime climatic conditions. According to the precipitation regime classification developed for Turkey, study area reflects a Mediterranean precipitation regime which receives the maximum rain in winter and the minimum in summer. Thornthwaite climate classification and water balance were applied to the stations. With regard to this, Karataş represents the climate type C2 B'4 s2 b'4 (subhumid, 4th degree mesothermal, rainfall deficient in summer, maritime); Adana represents the climate type C1 B'4 s2 b'4 (subhumid, 4th degree mesothermal, rainfall deficient in summer, maritime); Kozan represents the

climate type C1 B'4 s2 b'3 (subhumid, 4th degree mesothermal, rainfall deficient in summer, maritime); Ceyhan represents the climate type C1 B'3 s2 b'4 (subhumid, 3rd degree mesothermal, rainfall deficient in summer, maritime); Tufanbeyli represents the climate type C2 B'1 s2 b'2 (subhumid, 1st degree mesothermal, rainfall deficient in summer, continental) and Yumurtalık represents the climate type C2 B'4 s2 b'4 (subhumid, 4th degree mesothermal, rainfall deficient in summer, maritime). When the water balance was evaluated in the study area, there was a surplus of water in winter and a water shortage in summer.

Table 1: Geographic Coordinates of the Stations (Source: Turkish State Meteorological Service)

Station	Latitude (N)	Longitude (E)	Altitude (m)
Karataş	36° 34'	35° 23'	22
Yumurtalık	36° 46'	35° 47'	20
Ceyhan	37° 1'	35° 48'	30
Adana	37° 0'	35° 19'	27
Kozan	37° 26'	35° 49'	115
Tufanbeyli	38° 16'	36° 13'	1415

The average temperature is high in the study area because of the latitude. Continental climate is more effective than maritime conditions in Tufanbeyli due to its location, distance from the sea and altitude (Table 2).

Table 2. Distributions of Monthly and Annual Average Temperature at the Stations (1975-2010)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Karataş	10,2	11,0	13,6	17,2	21,0	24,7	27,3	28,0	26,0	21,8	15,9	11,7	19,0
Yumurtalık	10,5	10,8	13,4	17,1	20,9	24,6	27,2	27,9	25,8	21,8	16,0	12,0	19,0
Adana	9,6	10,5	13,5	17,6	21,8	25,8	28,3	28,6	26,2	21,7	15,3	11,0	19,1
Ceyhan	8,1	9,1	12,2	16,3	20,7	24,8	27,6	27,6	24,9	20,3	13,7	9,5	18,0
Kozan	9,6	10,4	13,5	17,6	21,9	26,1	29,0	29,0	26,3	21,9	15,6	11,1	19,3
Tufanbeyli	-2,9	-1,4	3,5	9,0	13,2	18,2	22,3	22,6	18,1	12,2	4,8	-0,9	10,0

The stations except Tufanbeyli have annual average temperatures over 18°C. The annual average temperature is 19°C for Karataş, 19.1°C for Adana, 18°C for Ceyhan and 19.3°C for Kozan. However, Tufanbeyli has an average temperature of 10°C. It is situated on high altitude and is under the effect of a continental climate (Fig. 3, Table 2). For all stations, the temperatures are always higher than the annual average of temperature between May and October. Sub-zero temperatures occur only in Tufanbeyli. Maximum precipitation is seen in winter and the minimum in summer in areas which have a typically Mediterranean climate (Table 3).

According to the monthly distribution of precipitation which is the one of identifiers of a Mediterranean precipitation regime, the rainiest month is December and the driest month is August. Summer droughts and winter maximum precipitation are due to general atmospheric circulation. Precipitation in cold periods occurs because of areas being located in frontogenetic places, whereas frontolysis in summer leads to air stabilization and strong draughts. The East Mediterranean basin is under the effect of cT air mass originating from the Great Sahara in summer. Quite stable, dry and hot air mass becomes more stable through the Mediterranean because the Mediterranean air mass is cooler than that in surrounding areas during this period. In other words, in summer air circulation in this area is controlled by southeastern air masses which are an extension of the monsoon climate (Erinç, 1957:51).

The study area receives rainfall ranging from 550mm to 850 mm. Annual total rainfall is 786 mm at Karataş, 834 mm at Yumurtalık, 659 mm at Adana, 727 mm at Ceyhan, 847 mm at Kozan and 567 mm at Tufanbeyli. Wind directions are partial perpendicularity to the Taurus Mountains causes limited orographic rise that leads to stations receive less rainfall compared to Mediterranean stations located in western and southeastern areas.

Table 3. Distribution of Seasonal Rainfall for Stations

	Winter (%)	Spring (%)	Summer (%)	Autumn (%)
Karataş	53	29	6	12
Yumurtalık	45	25	4	26
Adana	48	25	5	22
Ceyhan	45	29	5	21
Kozan	36	32	12	20
Tufanbeyli	35	34	7	24

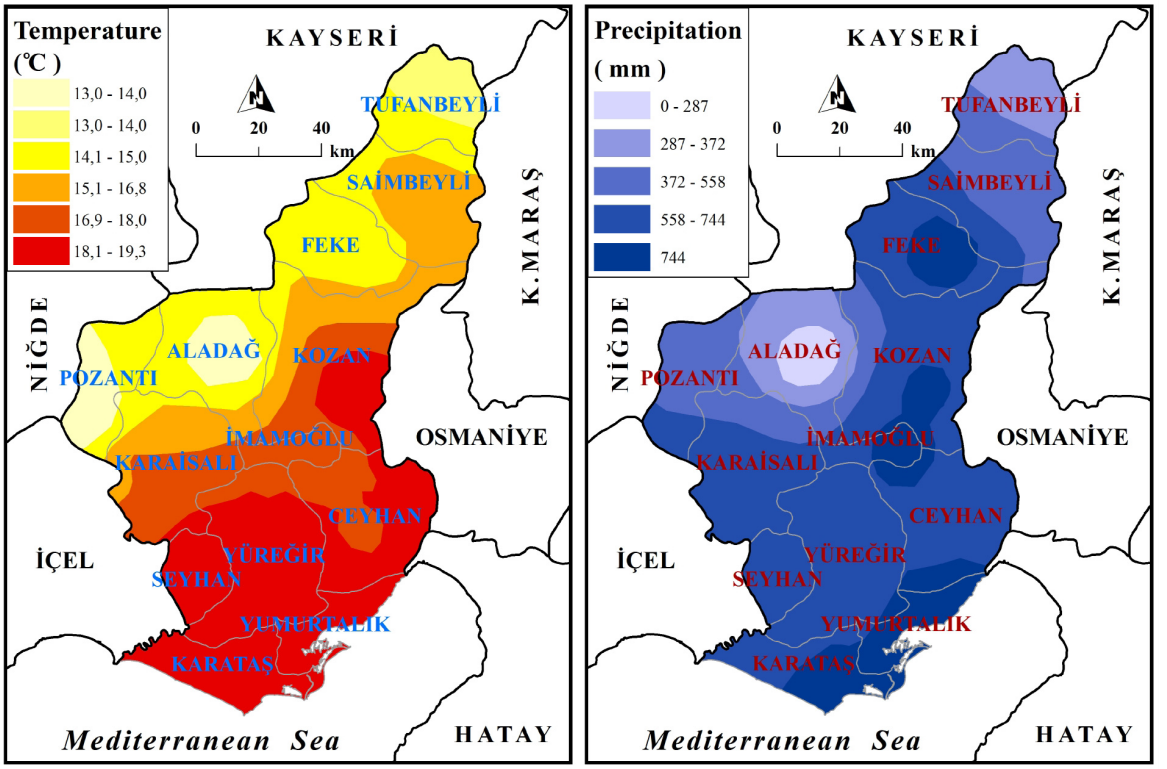

Fig. 3. Distribution of Temperature and Precipitation Parameters in Study Area

Table 4. Distribution of Monthly and Annual Relative Humidity Values for Stations

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Tufanbeyli	73	74	68	59	58	50	40	39	41	53	64	71	57
Adana	67	65	66	68	67	68	71	71	66	62	64	68	67
Kozan	57	58	60	64	62	60	62	63	57	51	54	59	59
Ceyhan	68	67	68	69	66	64	67	68	64	61	64	69	66
Karataş	66	66	69	72	73	74	76	74	68	63	61	66	69
Yumurtalık	61	63	66	71	73	75	76	75	68	61	59	62	67

Regarding Adana's climate, it is generally known by the public that "Adana's hot". However in fact, not only temperature but also humidity is a critical factor that must be considered. Relative humidity varies very little in summer compared to winter on the Mediterranean coast. Humidity is higher in summer at many stations located in coastal areas. The wind direction that describes this situation is contrary to the general rule. The breeze which blows from sea to land affects these coasts in summer. In this case, relative humidity increases at stations located in coastal zones (Erinç, 1996:349).

3. Results

3.1. Trend Analysis

Monthly and seasonal trend analysis of temperature, rainfall and humidity parameters of the selected stations were calculated but only seasonal M-K statistical results are represented in this section (Table 5).

3.1.1. Average Temperature

The temperature of the study represents the typical climatic properties of the Mediterranean region. There was a strong increase in average temperature between May and October. Even though there was a tendency towards positive increases in temperature throughout all months of the year in Yumurtalık district. In Adana, a slight decrease in average temperature during the winter season was calculated, whereas increases were determined during the rest of the year. There were statistically significant changes with respect to the strong positive temperature during summer. Furthermore, there were tendencies towards positive increases in temperature during all months of the year in both Kozan and Karataş. Strong temperature rises were also determined during summer in Ceyhan in addition to the increases all over the periods of the year. Moreover, no statistically significant changes were determined regarding average temperature for every month of the year in Tufanbeyli.

3.1.2. Minimum Temperature

Non–significant negative changes in winter and positive trends in the other periods were ascertained in Yumurtalık and Adana. Heat island effect due to urbanization in Adana influenced the minimum temperature. These results were in harmony with the previously proposed data (Karaca et al., 1995; Tayanç and Toros 1997; Karaca and Tayanç 1998; Çiçek and Doğan, 2005). There were significant increases in minimum temperature in all periods of the year other than winter in Kozan and Karataş, and there was is statistically significant increase at a level of 1 % in summer there. Both average and minimum temperature increases were also determined in Ceyhan. There were no statistically significant changes in minimum temperature in any periods of the year in Tufanbeyli.

3.1.3. Maximum Temperature

There were negative trends in the months of July and October, whereas positive trends were ascertained in the other months of the year in Yumurtalık. There were only statistical significant changes with respect to the seasonal trends in summer in Yumurtalık. Neither positive nor negative trends regarding maximum temperature in Central Adana were determined, whereas there was only a strong positive increase in August. No significant changes were determined throughout the entire year in Kozan, Karataş and Ceyhan. There were no statistically significant variations in maximum temperature regarding positive trends except for in June in Tufanbeyli.

3.1.4. Precipitation

According to the previous reports, no statistically significant changes with respect to either strong or weak decreases or increases have been determined on the Mediterranean coast (Türkeş, 1996; Türkeş et al., 2007; Hamurcuoğlu, 2009; Altın and Barak, 2012).

Determination and calculation of rainfall trends are difficult since rainfall reflects huge variable changes depending on location and time. The following results were obtained in the present study.

Table 5. Mann-Kendall u(t) values of temporal trends of temperature, precipitation and relative humidity

Station	Parameter	J	F	M	A	M	J	J	A	S	O	N	D
Yumurtalık	Ave. temp.	0,4	0,6	1,3	0,9	2,2*	4,2**	4,2**	5,1**	2,8**	2,6**	0,4	0,8
	Min.temp	-0,5	-0,4	2,4*	0,1	2,7**	2,4*	4,2**	4,5**	2,2*	1,4	0,5	0,5
	Max.temp	1,3	1,7	0,5	0,5	0,7	2,1*	-0,5	1,4	-0,2	1,3	0,0	1,5
	Prec.	0,5	1,3	-0,2	-1,3	-0,2	-0,5	0,0	-0,4	1,2	-2,0*	0,2	0,1
	RH	-2,4*	-2,4*	-2,7**	-2,4*	-2,7**	-2,9**	-2,4**	-3,5**	-3,1**	-1,9	-2,7**	-1,7
Adana	Ave. temp.	-0,9	-0,6	0,4	1,1	1,6	3,7**	2,7**	4,6**	1,9*	1,3	-0,7	-0,7
	Min.temp	-1,1	-1,0	1,8	-1,4	0,0	2,2**	2,5*	2,3*	0,2	1,7	0,6	0,4
	Max.temp	1,1	0,7	-0,2	-0,2	-0,7	-0,2	-0,1	2,6**	0,2	0,9	-0,1	0,8
	Prec.	-1,4	0,8	-0,1	-0,9	0,1	-1,1	1,6	1,0	0,0	-1,2	-0,6	-0,7
	RH	0,9	0,5	0,6	-0,4	0,1	1,4	3,4**	2,6**	1,0	1,0	1,4	1,0
Kozan	Ave. temp.	2,0*	1,4	0,9	0,5	0,6	1,7	0,7	1,2	0,1	2,4*	1,4	2,4*
	Min.temp	0,8	0,0	2,6**	1,7	3,7**	3,4**	3,5**	4,0**	2,0*	2,7**	2,0*	2,1*
	Max.temp	0,6	0,2	-1,4	-1,3	-0,4	0,9	-1,2	-1,4	-1,3	-0,6	-0,6	0,5
	Prec.	-1,2	0,9	-0,6	-2,1*	-0,4	-1,2	0,5	1,7	0,7	-1,1	0,3	-0,1
	RH	-1,0	-0,3	-0,6	-0,1	0,6	0,9	1,8	1,7	0,9	-0,2	-1,3	-0,9
Karataş	Ave. temp.	0,3	0,5	1,7	0,8	2,1*	3,5**	3,3**	4,3**	2,0*	2,3**	0,8	0,4
	Min.temp	-0,4	-0,2	2,4**	0,7	2,4**	3,8**	2,9**	2,8**	2,2*	1,5	0,9	0,4
	Max.temp	1,8	1,5	-0,5	0,1	0,0	1,3	-0,2	0,8	-0,3	1,6	0,5	1,0
	Prec.	-0,5	1,4	-0,7	-1,0	-0,1	-0,5	0,9	1,7	0,7	-1,4	-0,3	-0,3
	RH	-3,8**	-3,1**	-2,8**	-2,5**	-1,9	-2,7**	-1,9	-1,9	-2,0**	-2,0**	-3,9**	-3,8**
Ceyhan	Ave. temp.	0,9	0,7	1,1	1,3	1,6	3,8**	2,6**	2,8**	1,3	2,7**	0,6	1,1
	Min.temp	0,5	0,2	2,0*	0,3	2,9**	4,3**	4,9**	4,8**	2,9**	1,8	0,8	1,4
	Max.temp	0,5	0,7	-1,5	-0,7	-0,5	1,3	0,5	0,4	-0,1	0,2	-0,7	0,6
	Prec.	-1,2	2,2*	0,2	-1,2	-0,3	-1,1	-0,4	0,6	1,3	-0,4	0,8	0,0
	RH	-2,6**	-2,8**	-2,9**	-3,3**	-1,9	-2,1*	-1,1	-1,4	-0,3	-1,6	-1,1	-2,4*
Tufanbeyli	Ave. temp.	0,5	-0,1	0,3	0,9	0,0	1,2	0,1	0,1	-0,3	-0,1	1,2	0,3
	Min.temp	-0,6	-1,1	1,2	0,4	1,2	1,9	1,0	0,4	1,0	-0,6	1,5	1,3
	Max.temp	0,2	0,3	0,6	-0,4	-0,9	2,3*	1,9	1,7	0,0	-0,5	0,0	3,0
	Prec.	1,9	1,9	1,0	0,6	-0,8	0,1	-1,1	2,1*	-0,4	-0,1	-1,9	-0,7
	RH	1,8	1,6	0,9	0,7	0,5	-0,2	-0,6	-0,7	-0,4	-0,5	0,9	1,7

* Significant increase/decrease at level 5 % (±1.96) ** Significant increase/decrease at level 1% (±2.58)

Rainfall demonstrated a decreasing trend in spring in Yumurtalık. Decreasing trends were only determined in October in addition to non-significant changes with respect to the negative and positive trends in Yumurtalık. Even

though decreases in rainfall trends were obtained for the winter months, there were no statistically significant changes in Adana or Kozan districts. Karataş district was one of the locations demonstrating decreasing trends however, those trends were not significant. Changes in rainfall trends were not significant in any months of the year except February in Ceyhan.

No statistically significant changes were determined even though there were fluctuations in rainfall trends through the seasons of the year in Tufanbeyli. There was only a strong rainfall increase in August among the months in Tufanbeyli. Rainfall data did not reflect any statistically significant changes in Adana.

3.1.5. Relative Humidity

In the present study, there was a decreasing trend for relative humidity in Yumurtalık. Those variations were statistically significant. When observations of 7, 14, and 21 hours were evaluated, a strong decrease was determined in the observations of 14 and 21 h.

Relative humidity represented an increasing tendency through all periods of the year; however the strongest increase trend was determined to be in summer in Adana. Due to the increase in relative humidity, it will bring about sultry weather in terms of temperature.

Heat islands and urban canyons due to urbanization, weak evaporation, low saturation points and water vapor from anthropogenic sources contribute to the much greater humidity (Hage, 1975; Oke, 1987). Adana represents the climatic properties of anthropogenic origins in terms of both temperature and humidity. Kozan is another weather station where humidity increased in summer. However, the humidity tended to decrease in the cold period of the year and the size of the trend was negligible. Relative humidity was identified as decreasing at remarkable rates at the stations in Karataş and Ceyhan. There were very strong trends in seasons other than summer at both these stations. Relative humidity demonstrated an increasing trend in winter however it was in a downward trend in summer in Tufanbeyli. However, those changes were statistically non-significant.

3.1.6. Perceived Temperature

In this study, the perceived temperature related to humidity and temperature parameters was determined with the Humidex Index. Only the periods which 22°C in the index were included in the calculation.

The periods between June and August for Tufanbeyli, May and October for Adana and Kozan and June and October for Karataş, Ceyhan and Yumurtalık were evaluated since the temperatures were over 22°C during these periods. The calculated perceived temperature was subjected to M-K trend analysis in order to reveal the time-dependent temperature trends.

According to the findings, there was an upward trend in temperatures at all stations and this trend was statistically significant, except for at Karataş station. There was a remarkable increase, particularly in summer, in the perceived temperature in Adana (Table 6).

Table 6. Mann-Kendall u(t) Values of Perceived Temperatures Trends

Month	Adana	Kozan	Ceyhan	Yumurtalık	Karataş
June	4,54**	3,38**	2,32*	1,25	1,33
July	4,52**	2,32*	2,48*	3,06**	0,81
August	5,17**	3,12**	1,11	3,08**	1,39

* Significant increase/decrease at level 5 % (±1.96) ** Significant increase/decrease at level 1% (±2.58)

4. Conclusion

Temporal trends of temperature, rainfall, and humidity of stations were examined and the following conclusions were obtained:

Strong trends in average temperatures during the summer at all stations except Kozan and Tufanbeyli were determined and the trend was positive.

The increases in minimum temperatures were constant over time. Tufanbeyli demonstrated exceptional features with respect to the Mediterranean climate in terms of the temperature and rainfall patterns.

There were no statistically significant increases or decreases at any of the stations regarding monthly and seasonal maximum temperature trends

To ascertain the effects of climatic changes on rainfall pattern is very difficult due to the fact that there are no long-term rainfall data (Anonymous, 2007). According to the analysis of rainfall trends, there were no very strong decreases in spring in Yumurtalık or Ceyhan, in winter or spring in Adana and Kozan or in summer or fall in Tufanbeyli. There were non-significant increases in summer in Karataş, as well. Hence, clear conclusions cannot be deduced about rainfall trends based on the results obtained herein but there were not any very strong decreases during the winter months.

Anthropogenic climate features brought about by urbanization in the metropolitan city of Adana, were reflected in average and minimum temperature, humidity and consequently, perceived temperature.

Increasing of temperature and humidity especially with the heat island effect adversely influences the comfort conditions.

It was determined that temporal changes in climate in the study area led to average and minimum temperature. There were also non-significant changes in rainfall pattern in addition to the increases in perceived temperature which were consequences of upward trends in humidity and high temperatures.

Increasing higher temperatures could cause increases in perceived temperature by influencing the duration and frequency of heat waves in the deserts of North Africa and Arabia. Moreover, it was determined that there was water shortage because of the lack of rainfall during the warm period and increasing temperature trends.

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